Synthesis and Characterization of a Novel 2D Perovskite for Remote Strain Measurement

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Introduction

Graphical Abstract

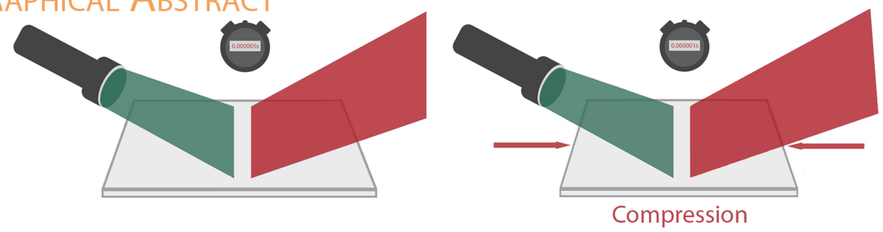


Figure 1. The graphical abstract depicts the change in emission duration while the material is under compression.

The goal of this project is to synthesize a material that will absorb UV light and emit visible light. When this material is compressed or lengthened the duration it emits for will change. This allows for the change in length (strain) to be measured with light.

Concepts and Goals

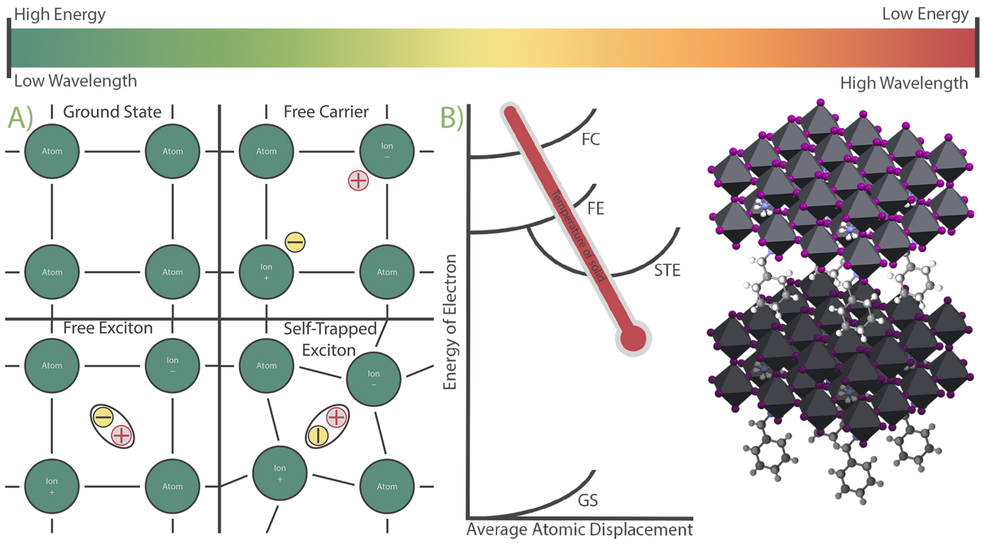


Figure 2. (top) Light is a spectrum described by inverses, energy and wavelength. Figure 3. A) (left) There are four different states an electron may be in. B) (middle) Each has a different energy level. Their proportions are temperature-dependent. Figure 4. (right)[3] The approximate structure of $(CMA)_2(FA)Pb_2Br_7$. (CMA is cyclohexanemethylamine, (FA) is formamidinium.

Self-trapped excitons create both a shift between emission and absorption energy as well as an emission duration (lifetime) dependence on temperature.[1,2] Both effects are caused by STE's lower energy, more stable, state. We hypothesize that temperature and strain will have similar effects. The material synthesized is $(CMA)_2(FA)Pb_2Br_7$ (2127). Its planar (2D) structure is hypothesized to increase the STE population and make the material more flexible. $(CMA)_2PbBr_4$ is an expected impurity due to its similar makeup.

Synthesis and Identification

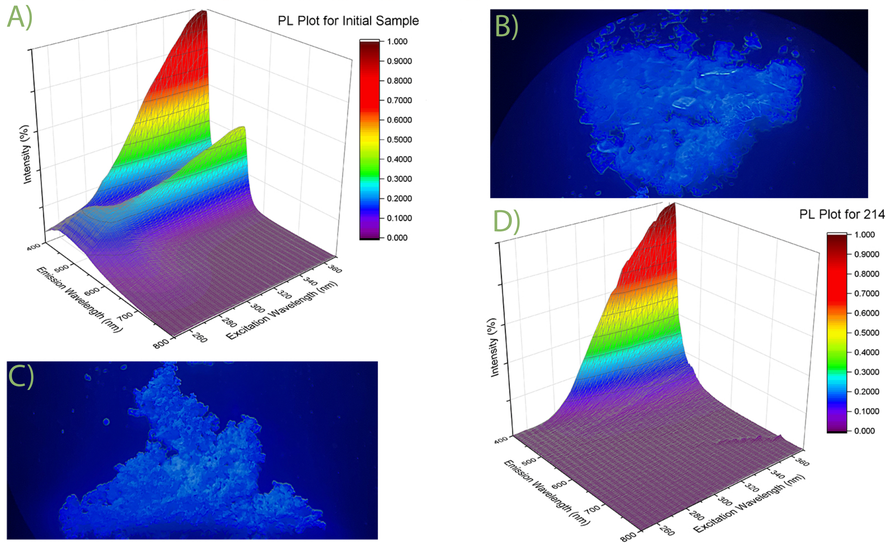


Figure 5A. (top) The PL for the initial sample has three peaks, both vertical and horizontal. 5B (right) The initial sample, as seen under UV light, is made of both plate-shaped and powder-shaped crystals. 5C (left) The 214 sample, as seen under UV light, is made entirely of powder. 5D (bottom) The PL plot for 214 shows a single peak with a noticeable energy shift.

$(CMA)_2(FA)Pb_2Br_7$ Synthesis (2127)

Examining the initial synthesis[3] showed it as being made up of a white powder with bright blue luminescence. Photoluminescence (PL) testing revealed the presence of impurities, later seen as clear plates. Impurity was expected to be from the lower 214 phase.

Results:

In order to identify a sample it must be pure. The first step is then to identify 214 as purity is expected from its simplicity.

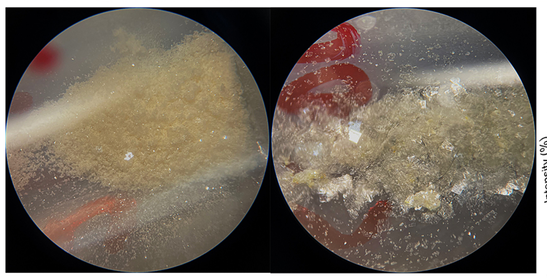
$(CMA)_2PbBr_4$ Synthesis (214)

The PL plot shows a sharp single peak with a shift between emission and excitation energy. Physical examination revealed this sample to be made entirely of white powder.

Results:

With purity achieved 214 has been identified as being made of white powder and having an emission peak at 405 nm. From this it is believed that the plates in the initial synthesis are the 2127 compound.

Final Synthesis



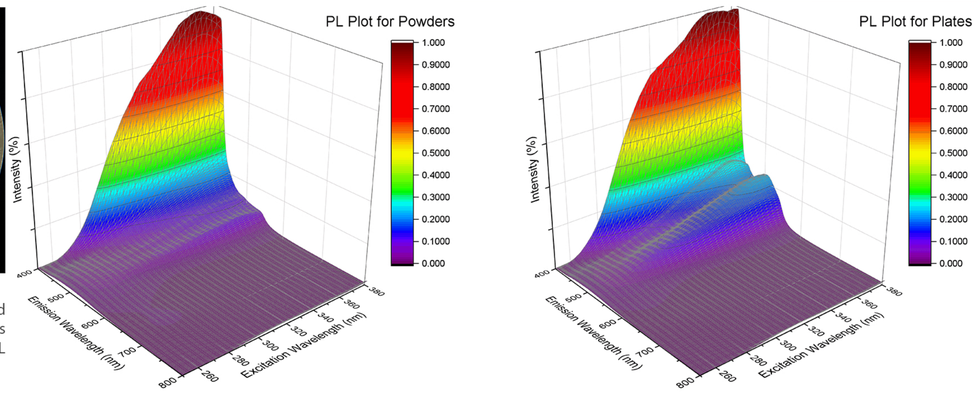


Figure 7. (above) After synthesis, the sample was sorted into powder (left) and plates (right). The sorting was imperfect. Figure 8. (right) The PL plot for powders (right) shows one large peak from the 214 and two much smaller peaks. The PL plot for plates is similar, except the two smaller peaks are larger.

The initial sample was recreated for the final batch. The two different materials formed crystals of distinct sizes allowing for simple, but imperfect, separation. Both graphs have a large peak characteristic of 214. They also share, at different intensities, a smaller dual emission band with a large energy shift.

Results:

214 is clearly present in both samples. 2127 also seems to be present in both as the dual peaks. In that case, the dual emission is characteristic of STE and FE emission. The dual peaks may also be caused by an impurity.

Further Work

After the identification of 2127, it must now be produced to certain standards. The main target is large crystals with defined edges. This should be achieved by more finely controlling the cooling process to control nucleation. Purity may be attained by adjusting the molar ratio of the (FA) precursor. Increasing its quantity may allow 2127 to be formed more easily. Once this is accomplished the crystals may be tested for their applicability for remote strain sensing.

References

1. Yakunin, S., et al. (2019). *Nat. Mater.* **18**: 846–852.
2. Gautier, R., et al. (2019). *JACS,* **141**: 12619-12623
3. Guo, S., et al. (2024). *Nat Commun*, **15**: 3001

Acknowledgements

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